EVTC™

Electric Vehicle Transportation Center

Semi-annual Program Progress Performance Report for University Transportation Center

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Semi-annual Program Progress Performance Report #7
Electric Vehicle Transportation Center
Submitted by:
University of Central Florida

I. Accomplishments

What are the major goals and objectives of the program?

The Electric Vehicle Transportation Center (EVTC) supports the U.S. Department of Transportation's strategic goal of planning for near-term integration of alternative fuel vehicles as a means to build a sustainable transportation system. The project objectives are to evaluate technologies, standards, planning and policies to ensure seamless integration of electric vehicles (EVs) into a complex transportation network and electricity grid. The EVTC bridges the gap between deployment of electric vehicles and the traditional transportation system.

What was accomplished under these goals?

Summary: The major activity of the past reporting period has been the completing of the final project research reports. During the period, four projects (numbers 1, 6, 16 and 19) were completed and the final project reports forwarded to DOT and the required associated organizations. Three additional final reports (numbers 3, 7 and 10) are completed and posted on the EVTC web site, but have not yet been forwarded. Final reports for the other 15 projects were being drafted and are in various stages of completion.

For this reporting period, EVTC researchers authored 7 project final reports, published 16 publications, made 12 presentations, attended 4 workshops and conferences, held or participated in 24 STEM events and have planned for 9 more STEM events. EVTC also held its 2nd EV Transportation & Technology Summit in October 2016. The Summit had 90 attendees and 14 sponsors.

Collaborative efforts for the period included a meeting with Florida Polytechnic University, the Florida Department of Transportation, AAA Auto Cub and Drive Electric Florida to discuss initiatives at FDOT's new Central Florida SunTrax vehicle and systems test facility. Researchers also met with St. Lucie County and Proterra to discuss the feasibility of deploying electric transit buses. Collaborative efforts with the stakeholder group Drive Electric Florida have included EV transportation and land use planning initiatives to governmental representatives at the state capital in Tallahassee and with the development of Volkswagen Mitigation Trust fund project recommendations for the Florida Chamber of Commerce. EVTC, the City of Orlando and Utah State University also discussed the development of a project to deploy a wirelessly charged shuttle van service in downtown Orlando and facilitated the demonstration of Proterra electric transit buses for LYNX, the Orlando area regional transit authority.

Research and Development Accomplishments

The EVTC R&D agenda has been conducting work on 22 projects. Seven are completed and the remaining projects are conducting the final work efforts and are writing final project reports. A summary of results for each project are presented in the following sections.

1. Implications of Electric Vehicle Penetration on Federal and State Highway Revenues

Objective: *Research the impact that increased use of electric vehicles will have on federal and state highway revenue sources. This work will identify existing laws and policies that govern highway, gas, and vehicle taxes and fees imposed on vehicles and summarize current trends and policy recommendations that may influence both the growth of the electric vehicle market and impact highway revenues.*

Accomplishments: This project is completed and the final project report has been forwarded to DOT and the required DOT associated organizations. The project 1 final report is posted on the EVTC web site at: http://fsec.ucf.edu/en/publications/pdf/fsec-cr-2052-17.pdf

2. Identify and Analyze Policies that Impact the Acceleration of Electric Vehicle Adoption11

Objective: *Examine state and national regulatory policies to determine their impact on the long term adoption of electric vehicles. The work will include discussion with Florida utility companies and with existing electric vehicle stakeholder groups. New policies and or regulations will be developed and suggested to the appropriate authorities. This project will also include Hawaii and Alabama.*

Accomplishments: Project has been collecting EV policies and reviewing activities done by U. S. DOE Clean Cities Alternative Fuel Data Center. Collaborative efforts with the stakeholder group Drive Electric Florida have included EV transportation and land use planning initiatives to governmental representatives at the Florida state capital and the development of Volkswagen Mitigation Trust fund EV project recommendations for the Florida Chamber of Commerce. Work has begun on drafting of final project report.

3. Electric Vehicle Charging Technologies Analysis and Standards

Objective: *Assess current and emerging technologies, codes and standards associated with Electric Vehicle Service Equipment (EVSE), Electric Vehicles (EVs) and the related infrastructure. The work will recommend policies and best practices to advance both vehicle and EVSE deployment. Collect and analyze 50kW DC fast charger usage data to evaluate electrical power impact.*

Accomplishments: This project is completed and the final project report is posted on the EVTC web site at: http://fsec.ucf.edu/en/publications/pdf/FSEC-CR-2057-17.pdf. The report has not yet been forwarded to DOT and other organizations. The project Abstract is as follows:

This project has evaluated the technologies and standards associated with Electric Vehicle Service Equipment (EVSE) and the related infrastructure, and the major cost issue related to electric vehicle (EV) charging -- the cost of utility power. The technology assessment report evaluated safety standards for infrastructure, highway and vehicles and the barriers and challenges of deploying an expanded network of EV charging stations. The report also made recommendations to help standardize and expedite EVSE infrastructure and charging network deployment.

For the cost analyses, the issue of demand charges for utility power are examined for two case studies – one assumes a dedicated utility electric meter connection for the EV charging station, the second case assumes that the EV charging station is part of the total electrical service for a commercial or industrial building complex. The costs associated with EV charging are the electricity used to charge the vehicle, the equipment needed to provide the electricity, the charging station maintenance and revenue collection. Both studies use a life cycle cost analysis. The cost analysis shows that high-power charging stations can significantly add to the facilities monthly electric bill because of utility demand charges and underutilization of the charging facility. A most important result from this work is that an energy management system (EMS) can lend itself to reducing or eliminating the portion of the electric bill associated with charger electrical demand. The detailed results from this project are presented in three reports.

4. Transportation Planning for Electric Vehicle and Associated Infrastructure

Objective: *Identify and examine transportation infrastructure planning models and related policy issues associated with the deployment of Electric Vehicles (EVs). Recommendations for planning and policy actions to accommodate EVs and EVSE infrastructure will be provided and an assessment of the how EVSE infrastructure planning will enhance EV acceptance will be produced. Infrastructure deployment feasibility models will also be developed.*

Accomplishments: EVTC held its second EVTC's *EV Transportation & Technology Summit* October 17-20, 2016. The four-day Summit attracted 90 attendees and had 14 sponsors for the event. The Summit provided an update on the current state of EV deployment, technology and planning. The Summit was proceeded by an EV and Battery Technology Workshop and an EV Powertrain, V2G Technology and EV Case Study Workshop. Summit details and presentations for the 2016 and 2015 Summits can be found at the Summit website, http://www.evsummit.org/.

Figure 1. EVTC's EV Transportation & Technology Summit

This project is completed and the draft final project report is receiving review and final editing before posting. The final report draft Abstract is as follows:

This project identified and examined transportation infrastructure planning efforts and models and how they accommodate the deployment of Electric Vehicles (EVs). Planning is a critical key to the successful adoption and deployment of any new transportation advancement. Electric transportation and the supporting infrastructure are unique new modes of transportation that require new and specific planning and policies to support their deployment. A most important output of the DOT's Electric Vehicle Transportation Center (EVTC) program is planning for EVs and their role in the future U.S. transportation network. This EVTC project brings together the planning elements of the EVTC program. These results are presented in the following five planning related subject areas: (1) Identification of 13 of the 22 EVTC program topics whose results have a direct role in the planning process; (2) Presentation of three case studies as examples of planning programs; (3) EV Transportation Planning Guidelines and Best Practices; (4) Volkswagen Settlement Beneficiary Mitigation Plan and its impact on the future of electrified transportation in the U.S., and (5) Outcomes from hosting of two annual EV Transportation & Technology Summits.

5. Prediction of Electric Vehicle Penetration

Objective: Identify past and present trends in electric vehicle sales to establish a baseline of electric vehicle penetration and to predict electric vehicle sales and sales characteristics within the U.S. Compare EV sales by states and evaluate the types of barriers to EV usage and the actions or incentives to overcome the barriers.

Accomplishments: This project is completed and the draft final project report is receiving review and final editing before posting. The final report draft Abstract is as follows:

The sales values for 2016 show a strong year of PEV sales both in the world and the U.S. China leads in yearly sales at 351,000 (a 64% increase for 2016 from 2015) followed by Europe at 221,000 vehicles sold. The U.S. is third at 159,000. These three regions comprise 94% of the global sales market. The world total of PEV sales for 2016 is estimated to be 744,000 up from 566,000 in 2015. The data shows that the overall world has a 37% growth rate for the past year. The world now has over two million EVs on the road. PEVs in the world market are rapidly growing due to the various country policies and to the development of lithium-ion batteries from both a technological and manufacturing standpoint**.** Within the U.S., the PEV sales results for 2016 show that 159,000 vehicles were sold as compared to 116,000 vehicles in 2015 for a yearly growth rate of 37%. On a state basis, California is the largest market with sales of 62,200 PEVs or 39% of the US sales. The total cumulative number of EVs sold in the U.S. over the seven year lifetime is now at more than 560,000 vehicles.

6. Electric Vehicle Life Cycle Cost Analysis

Objective: *Compare total life cycle costs of electric vehicles, plug-in hybrid electric vehicles, hybrid electric vehicles, and compare with internal combustion engine vehicles. The analysis will consider both capital and operating costs in order to present an accurate assessment of lifetime ownership costs. The analysis will include vehicle charging scenarios of photovoltaic (solar electric) powered charging and workplace charging.*

Accomplishments: This project is completed and the final project report has been forwarded to DOT and the required DOT associated organizations. The project 6 final report is posted on the EVTC web site at: http://fsec.ucf.edu/en/publications/pdf/fsec-cr-2053-17.pdf.

7. Assess Existing Software and Databases

Objective: *Evaluate the feasibility of using the existing software and data bases as platforms for analyzing the attributes of electric vehicles within present and future transportation infrastructure projects and models.*

Accomplishments: The final project report project is completed, but has not yet been forwarded to DOT and the DOT associated organizations. The project 7 final report is posted on the EVTC web site at: http://fsec.ucf.edu/en/publications/pdf/fsec-cr-2054-17.pdf. The final report Abstract is as follows:

This project evaluated the feasibility of using the existing software and data bases as platforms for analyzing the attributes of electric vehicles within present and future transportation infrastructure projects and models. The Florida based SunGuide and STEWARD databases were found to be abandoned and outdated. Thus, the Regional Integrated Transportation Information System (RITIS) database was selected to provide current and detailed vehicle transport data as input for transportation simulation models. Activities included review and formatting of RITIS vehicle transport data to provide vehicle numbers, directions and arrival times for a Florida Turnpike transportation model. A paper using the data was published and is cited below. The concept was to addresses both the system-level scheduling problem and the individual control problem, while requiring only distributed information about EVs and their charging at service stations along a highway.

8. Battery Technologies for Mass Deployment of Electric Vehicles

Objective: *Assess current and emerging battery technologies and the requirements for their commercialization; align with DOE targets for future EV batteries. Focus will be placed on battery technologies, charging cycles, lifetimes, safety, codes and standards, and economics.*

Accomplishments: A Matlab model was developed in the previous reporting period which simulated the use of vehicles to export power to a building. During the current reporting period, this approach was further refined to develop control algorithms that optimized battery operation to minimize building demand charges. For commercial buildings, electricity costs are associated with both energy (kWh) and power (kW) components. The power component is determined by monitoring the average power over a 30 minute window, and identifying the peak average power for a month's billing cycle. Utility companies will then charge the building operator a "demand rate", typically $10-20/kW. This "demand charge" often represents greater than 30% of a building's electricity costs. Reducing demand charges requires reducing the peak power level of a building during a monthly billing cycle, and this reduction can be met through vehicle-to-grid applications. However, predicting the peak power for a month is challenging. Research was conducted into identifying control algorithms for peak shaving applications, and to determine the potential impact these would have on battery lifetimes and building electricity costs.

Peak shaving control algorithms were developed by analyzing the FSEC office building's power demand for an entire year, and determining an optimized "power set point" for each month, as a function of battery capacity. This optimum set point was determined as the power level at which energy can be exported from the battery to reducing building demand without depleting the battery. For the purpose of the simulation, it was assumed that about 10 kWh of battery capacity could be available. This was determined based on using a Nissan Leaf with a 20 mile commute distance, and a desire to leave sufficient battery capacity after peak shaving to enable the driver to return home, in case the battery could not be recharged before the end of the day. After optimizing the controls, the simulation was re-run using a larger 2.5 year building power data set.

The simulation results indicate that the frequency of peak shaving using vehicles would actually be fairly low, on the order of once or twice per month. The expected impact on battery degradation from the frequency of peak shaving is expected to be minimal. However, the power output from the battery does appear to be quite high, in some cases approaching a 4C rate which implies the battery will be depleted in 15 minutes. These high rates of discharge may be detrimental to battery lifetime. In these cases, there may be a need to limit the power output from the battery to lower rates, which could reduce the effectiveness of this approach.

As it relates to the benefits to the building operator, these simulations indicate that as much as $200 per month may be saved through demand charge reductions. A slight increase in building energy consumption was observed, due to the inefficiencies of battery charging and discharging. The savings accrued by the building owner are likely to be used to pay for the equipment (e.g. bidirectional charger) and may also be used to compensate the vehicle owner in order to incentivize participation.

9. Electric Vehicle Battery Durability and Reliability under Electric Utility Grid Operations

Objective: *Determine the impact of electric vehicle use on battery life including charging cycles and vehicle-to-grid (V2G) applications. The work will identify conditions that improve battery performance and durability. Focus will be placed on providing battery data for system engineering, grid modeling and cost-benefit analysis.*

Accomplishments: Project work is continuing. Activities for the past period are as follows. Battery degradation is extremely important to EV technologies and is a function of several factors -- electrode chemistries, operating temperatures, and usage profiles (i.e. vehicle-only vs. vehicle-to-grid applications). The goal of this research was to assess such impact. Laboratory testing of commercial "18650" Li-ion cells was conducted in Hawaii Natural Energy Institute’s sustainable energy laboratory. The battery test plan used two separate experiments: a cycling experiment to assess the impact of both V2G and G2V strategies and calendar aging experiments to assess impacts of temperature and SOC.

The results to date have shown a measurable impact of V2G, temperature and SOC on the battery capacity loss and indicate that V2G strategies seem to affect cell performance. It was concluded that a V2G step twice a day increased the capacity loss by 75% and the resistance by 10%. This step once a day was found to accelerate the capacity loss by 33% and the resistance increase by 5%. There was, therefore, a clear detrimental impact of performing V2G under these aggressive conditions (P/4 for an hour which will discharge an additional 25 to 30% of battery capacity) on these cells. Forecasts based on the measurement results found that V2G implementation would decrease the lifetime of the battery packs below 5 years. To verify this result, the last 6 months of the project were devoted to an exhaustive electrochemical analysis of the battery degradation to identify whether or not the accelerated degradation observed for the V2G strategy is the same as the normal degradation. Results indicate that the degradation differs and that V2G usage not only degrades the cell faster but also impacts the negative electrode more intensely as some significant change in negative electrode kinetics were identified. Modeling is in progress to identify the impact on the remaining battery life to determine if it will reduce the 36 month estimated life and/or prohibit second use for these batteries. High temperature and high SOC also showed to be 3 to 4 times more detrimental effect than lower temperatures and SOC levels. Delayed EV charging (G2V) was found to have no impact so far.

10. Fuel Cell Vehicle Technologies, Infrastructure and Requirements

Objective: *Investigate state-of-the-art fuel cell vehicle technologies, and current infrastructure developments. Conduct comparative study of fuel cell vehicles and battery electric vehicles in terms of technical and economic viability.*

Accomplishments: The final project report is completed but has not yet been forwarded to DOT and the DOT associated organizations. The project 10 final report is posted on the EVTC web site at: http://fsec.ucf.edu/en/publications/pdf/FSEC-CR-2059-17.pdf. The final report Abstract is as follows:

Fuel cell electric vehicles (FCEVs) use hydrogen as fuel and exhaust only water and heat. They provide driving ranges and fueling times comparable to gasoline vehicles. Despite the advantages, FCEVs have been in and out of the spot light of the auto industry for the past several decades. As FCEVs finally moved from concept demonstration to commercialization in 2015, it is critical to analyze the opportunities and challenges this technology brings. This project placed emphasis on four areas: (1) Analysis of the development of FCEVs from a historic and technology point of view; (2) analysis of hydrogen fueling station infrastructure costs, technical and operational challenges, as well as safety codes and standards; (3) exploration of using fuel cell as vehicle range extenders through modelling; and (4) investigation of FCEVs as backup power options. The results of each research area are published as technical reports and a journal article. This final project report will provide an overview of these research areas and reiterate some key findings.

11. Electric Vehicle Grid Experiments and Analysis

Objective: *Provide data from experimental vehicle-to-grid laboratory simulations. The results of the experimental data will be used in the EVTC techno-economic simulation project.*

Accomplishments: This project is now complete and a final project report is in progress. Following review, the final report will be posted and submitted to DOT.

The final report draft Abstract is as follows:

This project has conducted vehicle-to-grid (V2G) experiments and has developed a low cost building energy management system (EMS). The V2G efforts also included the installation and operation of a Princeton Power System CA-30 bi-directional power system. These efforts were conducted in order to collect real data that could then be applied to conducting V2G experiments. The collection of building energy data was used to evaluate and verify development of a low-cost power management system. The EMS was directed toward reducing peak electrical demand for a commercial office building.

12. Electric Vehicle Interaction at the Electrical Circuit Level

Objective: *Investigate the effect of electric vehicle adoption on the circuit level utility distribution grid for both residential and commercial applications by determining the impact of electric vehicle charging and discharging to the grid.*

Accomplishments: This project is now complete and a final project report is in progress. Following review, the final report will be submitted to DOT and posted on the EVTC and HNEI websites. The final report draft Abstract is as follows:

The impacts of electric vehicles (EVs) on the electricity distribution grid was studied starting with development of a transient time domain model of a sub-circuit service area with PV power using EV charging as a means of mitigating transient over-voltages (TOVs) in various scenarios. This novel methodology for early detection of TOVs has shown that charging stations combined with the connected grid load of the EV can be used to eliminate over-voltage peaks and improve the response time and reliability of inverter-based islanding detection, thus, increasing grid reliability.

13. Optimal Charging Scheduler for Electric Vehicles on the Florida Turnpike

Objective: *Develop the methodology for analyzing the roadway traffic patterns and expected penetration and timing of electric vehicles (EVs) on the Florida Turnpike. The work will determine the requirements for electric vehicle supply equipment at turnpike plazas, the options for equipment siting and the economics.*

Accomplishments: This project is now complete and a final project report is in progress. The final report draft Abstract is as follows:

This project developed a methodology to simulate and analyze roadway traffic patterns and expected penetration and timing of electric vehicles (EVs) with application directed toward the requirements for electric vehicle supply equipment (EVSE) siting and purchasing/leasing at turnpike plazas. The project also developed a wireless-communication-based driver-assistance application that would optimize the location and timing of charging for individual drivers as well as efficiency of the overall charging network.

The first steps of the project were to develop the systematic methodology for analyzing expected penetration of electric vehicles (EVs) and their impacts on the overall transportation infrastructure. An analytical model consisting of three components was developed and applied. Furthermore, the stability and instability of the proposed model are also analyzed. The developed model was then applied to the Florida Turnpike network as a test system. As a result of three-year research efforts, five peer-refereed journal papers and six conference articles have been published, including the journal article on scheduling of EVs on the Turnpike.

14. Electric Vehicle Bus Systems

Objective: *Investigate the implementation strategy and the operation of an electric bus fleet and compare the operational data with a baseline diesel bus fleet. Model an electric public bus transportation system in a selected city.*

Accomplishments: This project is now complete and has completed a draft of the final report. This draft is receiving review and final editing before posting. The final report draft Abstract is as follows:

Pure electric buses (EBs) offer an alternative fuel for the nation's transit bus systems. To evaluate EBs in a transit setting, this project investigated the five electric bus fleet of the StarMetro transit system of the city of Tallahassee, FL. For the study, the implementing strategy, route distances and timings, charging times, fuel economies, impact of chargers, and maintenance and operational characteristics were analyzed. The results were compared to a baseline five diesel bus fleet. The results showed that even with a four-fold improvement in fuel efficiency, the operational costs of electric buses were only 10% lower than that for diesel buses. The results showed that for EBs, the electricity cost due to demand charges was identified to be a major contributor to the electricity cost. To mitigate the high demand charges, researchers developed a method that can reduce the demand charge by optimizing the charging strategy. By using the optimized charging schedule, the demand charges can be reduced by up to 45%.

15. Electric Vehicle and Wireless Charging Laboratory

Objective: *Furnish, equip and operate an EV and Wireless Charging Laboratory within the FSEC laboratory facilities. This facility will function as a laboratory where EV vehicles are charged and discharged through a computer assisted communication network and where wireless chargers are evaluated.*

Accomplishments: This project is now complete and a final project report is in progress. The final report draft Abstract is as follows:

Figure 2. PPS CA30 in EVTC lab

Wireless charging tests of electric vehicles (EV) have been conducted at the EVTC Wireless Lab located at the Florida Solar Energy Center, Cocoa, FL. These tests were performed to document testing protocols and to evaluate standards and wireless operational charging characteristics. The presented results are for a Plugless wireless charger of 3.3 kW rated input power operating at 20 kHz resonant frequency. The electric and magnetic fields emanating from the transmitter were measured at varying separation and offset distances. The results show a maximum charging efficiency to be 94% at about 19 cm (7.5 in) of vertical separation.

16. Electric Vehicle Fleet Implications and Analysis

Objective: *Evaluate the implementation and effectiveness of electrical vehicles used in fleet operations. The project will evaluate present usage through case studies. The results will be used to evaluate other vehicle applications and to determine how EV fleet adoptions could impact overall rates of market penetration and what are the programs or incentives that could encourage EV fleets.*

Accomplishments: This project is completed and the final project report has been forwarded to DOT and the required DOT associated organizations. The project 16 final report is posted on the EVTC web site at: http://evtc.fsec.ucf.edu/publications/documents/FSEC-CR-2031-16.pdf.

17. Electric Vehicle Energy Impacts

Objective: *Evaluate the impacts of electric vehicles and associated renewable power generation on reduction of petroleum imports to Hawaii. The analysis will concentrate on the Island of Oahu and will include the effects of number of vehicles, charging strategies, renewable energy penetration levels and green-house gas reductions.*

Accomplishments: This project has been completed and the final project report is receiving editing. The final report will be submitted to DOT and posted on the EVTC and HNEI websites. The final report draft Abstract is as follows:

Figure 3. Hawaii Charging Station (photo K. McKenzie)

The objective of this research project was to evaluate the impacts of electric vehicles (EVs) and renewable wind and solar photovoltaic (PV) power generation on reducing petroleum imports and greenhouse gas emissions to Hawaii. In 2015, the state of Hawaii mandated fossil fuel electric power displacement by imposing Renewable Portfolio Standards (RPS) that will reach 100% renewable electricity generation by 2045. With small, remote and isolated island electricity grids, utilities in Hawaii face unprecedented technical and economic challenges to meet these goals with exceedingly high levels of intermittent wind and PV power generation. To meet these RPS goals, EVs become increasingly important in helping to balance intermittent power generation by providing a controllable load, and potentially an energy storage medium as well. In this work, high fidelity grid modeling and analysis of EV energy use and emissions was conducted for the Island of Oahu with the focus on the number of vehicles, charging strategies, and wind and PV penetration levels at present and in the future. Comparisons were made for different vehicle types and fuel mixes. Additionally, the state of EV integration in Hawaii was assessed and reported, including current EV infrastructure and challenges.

Although modeling and analysis has been completed under this UTC project, the project efforts continue under other funding (the Hawaii Environmental Response, Energy, and Food Security Tax, aka Barrel Tax). These efforts are being conducted to increase understanding of EVs effect and value in balancing renewable energy integration on the power grid, along with EV energy charging and storage as a means of improving power quality and stability. This work is directly applicable to growing EV populations being charged from renewables on isolated grids, micro-grids and large grids at the distribution or circuit level.

18. Socio-economic Implications of Large-scale Electric Vehicle Systems

Objective: *Develop models to evaluate the socio-economic implications of a large-scale electrified transportation sector. Model factors include effects of vehicle and infrastructure safety requirements, standardization of vehicle components for safety and charging, electric vehicle supply and after-market economies, displacement of petroleum fuels and impacts of sustainable development (social, environmental and economic).*

Accomplishments: The research team has focused on the following areas:

Sport Utility Vehicles: A life cycle assessment has been conducted to assess their cradle-to-grave environmental impacts for life cycle phases ranging from manufacturing to end-of-life recycling. A hybrid economic input output life cycle assessment (EIO-LCA) method is used to estimate the environmental impacts (greenhouse gas emissions, energy consumption, and water withdrawal) of sport utility vehicles. This life cycle assessment is also supplemented with a sensitivity analysis, using a Monte Carlo Simulation to estimate the possible ranges for total mileage of operation and fuel economy, and to account for the sensitivity of the EIO-LCA output. The operation phase is the major contributor to the overall life cycle impact of sport utility vehicles in each fuel/power category. Furthermore, among the selected vehicles, the battery electric vehicle has the lowest greenhouse gas emissions (77 tons) and the lowest energy consumption (1,047 gigajoules) even though the environmental impact indicators for the battery manufacturing process are significantly large. The plug-in hybrid vehicle, on the other hand, demonstrates an optimal performance between energy use and water withdrawal (1,173 gigajoules of energy consumption and 1,370 kgal of water withdrawal). In addition, all of the fuel-powered vehicles demonstrated similar environmental performances in terms of greenhouse gas emissions, which ranged between 100 tons and 110 tons, but the hydrogen fuel cell vehicle had a significantly large water withdrawal (2,253 kgal). Since the majority of the overall impact stems from the operation of the vehicle in question, their complete elimination of tailpipe emissions and their high energy efficiency levels make battery electric vehicles a viable green option for sport utility vehicles. However, there are uncertainties beyond the scope of this study that can be considered in future studies to improve upon this assessment, including (but not limited to) regional differences in source of electricity generation and socio-economic impacts.

19. Economic Impacts of Electric Vehicle Adoption

Objective: Examine the predicted levels of electric vehicle adoption to analyze the opportunity of using EVs as a grid stabilization tool for Hawaii, including GHG emissions impacts. Assess factors that affect EVs adoption, including regulatory mechanisms.

Accomplishments: This project is completed and the final project report has been forwarded to DOT and the required DOT associated organizations. The project 19 final report is posted on the EVTC web site at: http://fsec.ucf.edu/en/publications/pdf/fsec-cr-2047-17.pdf.

20. Techno-economic Analyses of Large-scale Electric Vehicle Systems

Objective: *Develop a computer model to evaluate the techno-economic implications of a large-scale electrified transportation sector. The model factors include developing a network of electric vehicles that interact with the electric grid, the infrastructure for electric vehicle charging, integrating the* *transportation and power systems into the urban setting, studying the impact of distributed energy storage and determining the economic impact of increased renewable energy and EVs on the grid.*

Accomplishments: This project has developed computer models to evaluate the techno economic implications of a large-scale electrified transportation sector. The current research focuses upon several innovative aspects of vehicle-to-grid (V2G) charging and grid feedback. These results show that energy storage and reactive power supplied by EVs through V2G operation can be coordinated to provide voltage support, thus reducing the need of grid reinforcement and active power curtailment and in turn improving EV charging capacity of the overall system. The project activities are now complete and the drafting of a final report is in progress.

21. Effect of Electric Vehicles on Power System Expansion and Operation

Objective: *Examine the effects of electric vehicles on electric power systems and their operation. This work includes using an existing Hawaii developed model that will be validated against a large scale utility model. The work will evaluate the benefits of optimally-timed EV charging, the requirements and costs of electric grid infrastructure to serve different types of vehicle fleets, and the effects of battery duty cycles used in the vehicle and in vehicle-to-grid applications.*

Accomplishments: This project developed the SWITCH power system model. SWITCH is a utility grid model that includes spinning reserves; part-load heat rates; fuel markets; battery storage; modeling of arbitrary, high-complexity demand functions and techniques to represent the charging requirements and flexibility of the EV fleet. Other model developments have been the integration of load and energy profiles into power system production cost and capacity expansion. The model has been verified using Hawaii data. This project has been completed and a final project report is in progress.

22. Automated and Connected Vehicle Implications and Analysis

Objective: *This project will evaluate the usage and implementation of automated and connected vehicles (AV/CV). The project evaluation will be done through case studies with the results being applied to determine appropriate vehicle applications and how EVs will participate in this new transportation future.*

Accomplishments: This project is completed and the draft final project report is receiving review and final editing before posting. The final report draft Abstract is as follows:

Automated and connected vehicles (ACV) and, in particular, autonomous vehicles have captured the interest of the public, industry and transportation authorities. ACVs can significantly reduce crashes, energy consumption, pollution and the costs of congestion which in turn will offer a fundamental change to the future U.S. transportation network. The objective of this project was to evaluate ACV technologies, activities, laws and policies that are now in place or proposed and to assess future ACV usage. The assessment also evaluates the highest level of automated vehicles called autonomous or self-driving vehicles and includes how electric vehicles (EVs) will participate in the future ACV transportation system. The results show that the three areas of largest activities are: (1) Autonomous vehicle development and demonstration, (2) Connected vehicle and their application to safety improvements, and (3) The interaction of autonomous and electric vehicles. The future dollar value in ACV technologies is huge with multi-billion dollar investments being made by auto manufacturers, ride sharing companies and technological innovators all looking to establish their positions. EVs will play a major role in this new future due to regulatory reasons (no urban emissions) and other reasons (fewer moving parts, reduced maintenance, and vehicles that are configured to drive, steer, brake and recharge by wire).

External Collaboration Accomplishments

Key collaborations are:

1. National Fire Protection Association - EVTC in coordination with NFPA has continued training on electric vehicles as well as other alternative fuel vehicles for First Responders (Project 2).
2. Clean Cities - On-going collaboration on projects to support EV adoption (Project 2)
3. Facilitated the demonstration of Proterra electric transit buses for LYNX, the Orlando area regional transit authority. (Project 3)
4. EVTC and Proterra met with St. Lucie County to discuss the feasibility of deploying electric transit buses. (Project 4)
5. Drive Electric Florida - EVTC worked with DEF on the development of Volkswagen Mitigation Trust Fund infrastructure project recommendations for the Florida Chamber of Commerce, and a separate initiative to introduce EV transportation and land use planning to governmental representatives at the state capital in Tallahassee (Project 2 and 4).
6. City of Orlando - EVTC, the City of Orlando and Utah State University discussed the development of project to deploy a wirelessly charged shuttle van service in downtown Orlando. (Project 15)
7. GE Energy Management, Energy Consulting - Monthly steering committee meetings with HNEI, UH, Hawaiian Electric Company and other stakeholders for the HNEI-GE high fidelity grid modeling. (Project 17)
8. Hawaiian Electric Company - On-going collaboration on modeling methods for the utility's long-term Power Supply Improvement Plan. (Project 17)
9. Florida Department of Transportation – Met with Florida Polytechnic University, the Florida Department of Transportation, AAA Auto Cub and Drive Electric Florida to discuss initiatives at FDOT's new Central Florida SunTrax vehicle and systems test facility.(Project 22)
10. Florida Department of Transportation - Doug Kettles, appointed to FDOT Florida Automated Vehicles Technology and Infrastructure Working Group (Project 22).
11. Electrathon of Tampa Bay - On-going collaboration with the non-profit organization, which is dedicated to promoting electric vehicle technology through hands-on electric go-cart design, building and endurance racing (STEM activities).
12. Eastern Florida State College - On-going collaboration with the local Brevard County College to promote electric vehicle technology (STEM activities).

Education and Workforce Development Accomplishments

University of Central Florida

The UCF Department of Civil, Environmental, and Construction Engineering (CECE) offered one course in the spring quarter 2017 taught by UTC project faculty:

CCE 3930H – Systems Analysis for Sustainability: Introduction to the principles of sustainable engineering; the use of systems thinking and life-cycle thinking in understanding sustainable systems. Development of sustainability metrics; applications to sustainable transportation, energy-transportation nexus, and electric vehicles.

The UCF Electrical Engineering Department offered seven courses as undergraduate electives and entry-level graduate courses.

Fall 2016:
EEL 5937 Communications and Networking for Smart Grid
EEL 4216 Fundamentals of Electric Power Systems
EEL 6269 Advanced Topics in Power Engineering

Spring 2017:
EEL 5291 Distributed Control and Optimization for Smart Grid

EEL 6272 Smart Power Grids Protection
EEL 4932 Global energy issues
EEL 4216 Fundamentals of Electric Power Systems

Tuskegee University

Tuskegee has offered the following 3 credit hour course in the spring and fall of 2016 and it is scheduled to be offered in the fall of 2017.

Physics 570 (3CH) Renewable Energy and Electric Vehicles: Course on fundamentals of renewable energy and electric vehicles for engineering, chemistry and physics majors.

Tuskegee University Battery Lab

Tuskegee University has completed the setting up a battery laboratory equipped with impedance analyzer, potentiostat, power supply and infra-red camera. This setup will enable students to investigate battery performance changes as well as the temperature effects of battery charging/discharging cycles. Specifically, electrode and electrolyte performances with degradation can be nondestructively characterized by using the impedance spectroscopy setup. All of the results will ultimately augment the understanding of advanced battery chemistry to prepare students for future careers. The lab supports faculty and student lab experiments and student projects. During the period, two student authored poster papers were presented at Alabama Science meetings using lab results. The work of training students in lab activities continues.

Workforce Development

As part of the STEM program and STEM presentations, staff has investigated career opportunities related to EVs. The EVTC has also partnered with the Central Florida Clean Cities Coalition on several workforce initiatives that have been offered in partnership with Florida workforce agencies.

Technology Transfer Accomplishments

As previously reported, UCF and the Central Florida region have established extensive business incubator style programs. The two major programs are the Innovative Corps, an NSF funded effort, and the high-tech BRIDG research center near Kissimmee, FL. (The BRIDG center stands for Bridging the Innovation to Development Gap and it was previously called the Florida Advanced Manufacturing Research Center.) BRIDG opened its doors in March 2017 and is a 109,000 square-foot research and manufacturing facility. BRIDG goals are to attract pioneer manufacturing processes and materials designed to advance the production of smart sensors and photonics devices. EVTC continues to investigate EV manufacturing for BRIDG location.

Diversity Accomplishments

University of Central Florida -- The primary components of the EVTC diversity program efforts are university education, STEM and K-12 activities, which include curriculum development, professional development for educators and education and outreach to students from underserved communities.

The EVTC program includes STEM project-based learning activities which have an EV focus. Two of the programs are the Junior Solar Sprint (JSS) for fourth through eight graders and the Electrathon program, which targets high school and college level students. Junior Solar Sprint involves designing and building a solar powered, model-sized vehicle that is equipped to successfully carry a ping-pong ball (passenger) down the track as quickly as possible. The vehicle is also designed to switch to battery power in the event of overcast skies. The Electrathon is a program where teams design, build and race an electric go-kart that must be driven by a team member and complete as many laps within an hour as possible, without completely draining the vehicle’s battery. Both activities are fun hands-on efforts that integrate STEM learning and require problem-solving, critical thinking and teamwork.

Professional development opportunities are offered to teachers and after school program leaders interested in implementing the EV focused, STEM programs. Efforts to work with the 21st Century Community Learning Centers (CCLC) and Florida After-School Association continue. Although the organizations are interested in partnering, it has been difficult to schedule the necessary professional development for these educators due to staffing and time constraints. FSEC staffers have made resources available to these organizations, as well as offered technical assistance in order to implement these activities within Brevard County and have begun working with STEM Tech, which is an afterschool program located in a community center within a government housing area in Melbourne, FL. Volunteer staff from STEM Tech attended a teacher workshop on January 21, 2017 and they are now working with students to design and build Junior Solar Sprint vehicles. They are also going to participate in the Electrathon program by collecting equipment and materials for next season.

Education and outreach events, called EnergyWhiz Expos, occurred in various parts of Florida including Tallahassee, Parrish, Tampa, Orlando and Gainesville. By offering regionally-based opportunities, more students have been able to participate in STEM opportunities. Each of the five EnergyWhiz Expos included Junior Solar Sprint competitions. The statewide EnergyWhiz event will be held on May 13, 2017, at the Florida Solar Energy Center in Cocoa. Over 1000 participants are anticipated. This STEM-centered event includes several EV events, including JSS, Electrathon and an Electric Vehicle showcase. The Electrathon of Tampa Bay group continues as a partner to engage more students in the Electrathon program.

The UCF and Seminole State College (SSC) Electrathon teams will be participating in the EnergyWhiz event at FSEC on May 13, 2017. Both teams received assistance from the EVTC program.

The UCF team has been active in learning more about electric vehicle technology and the engineering process. After competing in the first race of the season on September 24, 2016, they had ideas for improvements to their vehicle and took the opportunity to connect with several of the more experienced Electrathon teams, who were very happy to share information. The team made improvements to their vehicle and they were able to participate in the Longwood Holiday Parade on December 3, 2016, in Seminole County. This gave the team a chance to talk with the students and the public about EV's.

Figure 4. University of Central Florida EV Team, at the Longwood Holiday Parade

During the January 21, 2017, Solar Workshop for Teachers that was held at FSEC, the UCF Electrathon team brought out their vehicle and discussed it with the teachers. Several teachers took turns driving the vehicle around the parking lot. This had a huge impact, particularly on two of the participants who were working with underserved students in a program called STEM Tech. These two educators are now determined to bring this program to their students. Also during this time, as the UCF Electrathon vehicle was being driven around the parking lot by a teacher, one of the team members casually mentioned to the group that he had recently applied for a summer internship at Texas Instruments. He said that his work on the Electrathon vehicle – the hands-on experience – is what raised him above the competition. He got the internship and starts May 15, 2017.

EV curriculum development includes both the JSS and Electrathon programs. A video on how to evaluate design components of a JSS vehicle was created at FSEC and is available upon request. Efforts to adapt Electrathon lessons are on-going and rely on input from the various Electrathon teams, which is still underway. The JSS curriculum that was redesigned to create a supplemental stand-alone unit with more background information and instructions has been made available through the FSEC website.

Efforts to inform teachers and after-school care providers of these materials have included emails, announcements at workshops, conferences and presentations.

Tuskegee University

Electric Vehicle Transportation Center (EVTC) Day, Tompkins Hall, Tuskegee University

Tuskegee University is in the process of planning for its annual EVTC day meeting for 2017 to be held either September 7, 2017 or September 14, 2017. The reason for the meeting in September rather than the summer is that the latter time will increase the participation of high school students since students are off in summer. Alabama Power Company will again supply EV rides, speakers and financial support. A photo of last year's event is shown in Figure 5.

Figure 5. June EVTC Workshop, presented by Tuskegee Physics Dept.

List of STEM Activities for the period follows:

1. October 12, 2016 – Florida After-School Association Conference, Orlando, FL – Facilitated two sessions on designing circuits with playdough. Provided information to 60 participants regarding the EVTC program, Junior Solar Sprint (JSS), Electrathon and EnergyWhiz.
2. October 21, 2016 – Florida Association of Science Teachers Conference, Orlando. Facilitated three sessions covering topics in photovoltaics, solar thermal technology and hydrogen fuel cells. Approximately, 75 participants were provided information about the EVTC program, JSS, Electrathon and EnergyWhiz.
3. October 25, 2016 – Speaker Series Event at FSEC, "Climate Change & What you Can Do About It". Electric vehicles and the EVTC program were discussed. Approximately 25 attendees.
4. November 7, 2016 – Eastern Florida State College students at FSEC for presentation and tour. FSEC researchers discussed engineering and EVTC research ideas with approximately 25 pre-engineering students.
5. November 15, 2016 – STEM Summit at Mack Technologies, Melbourne, FL. Information was provided to 35 attendees about EVTC, EnergyWhiz and professional development opportunities for educators offered at FSEC.
6. December 3, 2016 – Longwood Holiday Parade, UCF Electrathon team showcased their electric vehicle. Approximately 500 people attended.
7. December 9, 2016 – Girls Engineering Club from Milwee Middle School at FSEC for hands-on energy focused STEM sessions, including squishy circuits, solar technology and energy efficient design in buildings. Approximately 40 females participated.
8. December 16, 2016 – Brevard County Media (Maker Space) Specialists at FSEC for Hands-on STEM sessions including squishy circuits, paper circuits and soldering. Provided a session to the entire group on EnergyWhiz and STEM. Approximately 100 attendees.
9. January 4, 2017 – Meeting with STEM Tech Director at FSEC about partnership opportunities, as well as EV and other energy related projects for students in the STEM Tech program.
10. January 9, 2017 –*Sustainability Symposium – Ready for Anything*, Orlando, FL Participated in break-out sessions, provided information about EVTC and EnergyWhiz.
11. January 14, 2017 – JSS and Solar Cooker Workshop for Teachers, Sarasota, FL. Facilitated workshop for approximately 25 participants.

12. January 21, 2017 – Solar Workshop for Teachers at FSEC. UCF Electrathon team also showcased their vehicle and discussed their design process and challenges. 32 Participants.
13. January 26, 2017 – STEM and Literacy Event at FSEC. EnergyWhiz presentation included as a required session. Approximately 200 middle school students participated.
14. February 2, 2017 – STEM Tech meeting at FSEC. STEM Project information and implementation plan discussed among five attendees.
15. February 3, 2017 – Meeting with Kathryn Wheeler, State Supervisor, Architecture, Construction & Energy, Division of Career and Adult Education, Tallahassee, FL. Discussion regarding EV and Green Energy workforce opportunities and educational pathways for underserved students.
16. February 3, 2017 – Meeting with John Leeds, Florida Energy Office, Fl. Dept. of Agriculture and Consumer Services, Tallahassee, FL. Discussion regarding energy education outreach to underserved students through EnergyWhiz Expos and professional development for educators.
17. February 4, 2017 – Panhandle EnergyWhiz Expo, Tallahassee, FL. Junior Solar Sprint and Solar Energy Cook-off projects were showcased. Approximately 70 attendees.
18. February 11, 2017 – SECME at UCF main campus (STEM event). Judged Energy Transfer Machine projects and provided information about EnergyWhiz activities to students and teachers. Approximately 400 in attendance at SECME event.
19. February 20, 2017 – FPL Solar Competition and EnergyWhiz Expo, Parrish, FL. Activities included: Solar Power Plant Dedication Ceremony, JSS, Energy Innovations and Solar Energy Cook-off events. Approximately 400 attendees.
20. February 24, 2017 – Eastern Florida State College students at FSEC for presentation and tour. Focus on EVs and solar technology. Approximately 20 students participated.
21. March 2, 2017 – Technology Student Association (TSA) South East Regional Event, Orlando, FL. Provided JSS track and equipment for JSS competition. Approximately 30 teams participated.
22. March 25, 2017 – West Central EnergyWhiz Expo, Tampa, FL. Junior Solar Sprint and Solar Energy Cook-off projects displayed. Approximately 80 students participated.
23. March 29, 2017 – Meeting with STEM Tech facilitators, Community Center in Melbourne. Materials were provided and strategies discussed for engaging students in JSS and Solar Energy Cook-off programs.
24. March 30, 2017 – Eastern Florida State College, Rotaract Meeting. Presentation about EnergyWhiz and Electrathon provided to 25 college members of the Rotaract Club.

Awards

The UTC Outstanding Student for 2016 was awarded to Ms. Sherilyn Wee from the University of Hawaii. She received the award at the DOT Washington meeting in January 2017.

Metrics

Performance metrics for the EVTC project are designed to drive improvement and characterize progress and effectiveness. The metrics performance table for PPPR#7 is provided below.

Metric	Research Activities	Industry Collaboration	Educ. & Workforce Dev.	Tech. Transfer	Diversity
Productivity	S	EG	EG	EG	EG
Timeliness	S	S	S	EG	EG
Quality	S	S	EG	EG	EG

NI - Needs improvement, S - Satisfactory, EG - Exceeds goals, or C - Completed.

In addition to the above metrics, a part of EVTC peer review has been the continued updating of each project's completion schedule and assistance in the writing of final project reports.

What opportunities for training and professional development has the program provided?

Training and professional development activities have been provided to students, industry professionals and the public by the three partner universities. These activities have been previously presented in the Education and Workforce Development Accomplishment sections above and in the following section of results dissemination.

How have the results been disseminated?

Project results have been disseminated by presentations, publications, workshops and conferences.

Final Research Project Reports:

1. Kettles, Doug, "Electric Vehicle Fleet Implications and Analysis", FSEC-CR-2031-16, Nov 2016, *Project 16*.
2. Schleith, Kevin, "Implications of Electric Vehicle Penetration on State and Federal Highway Revenues", FSEC-CR-2052-17, Feb 2017, *Project 1*.
3. Raustad, Richard, "Electric Vehicle Life Cycle Cost Analysis", FSEC-CR-2053-17, Feb 2017, *Project 6.*
4. Coffman, Makena, "Economic Impacts of Electric Vehicle Adoption", FSEC-CR-2047-17, Feb 2017, *Project 19.*
5. Kettles, Doug, Raustad, Richard, "Electric Vehicle Charging Technologies Analysis and Standards", FSEC-CR-2057-17, Feb 2017, *Project 3.*
6. Raustad, Richard, "Assessing the SunGuide and STEWARD Databases", FSEC-CR-2054-17, Feb 2017, *Project 7.*
7. Qin, N, Brooker, R P, Raissi, A, "Fuel Cell Vehicle Technologies, Infrastructure and Requirements", FSEC-CR-2059-17, April 2017, *Project 10.*

Presentations:

1. Doug Kettles, *Electric Transportation, Planning for the Future*, FSEC/UCF, Urban Land Institute, Tampa, FL, March 2, 2017.
2. Doug Kettles, *Electric Transportation, Far Ranging and Affordable,* Go Solar Day, Plantation, Florida, March 30, 2017.
3. Jay Griffin, Marc Matsuura, Matthieu Dubarry and Richard Rocheleau, "Hawai'i Energy Storage Overview", Hawaii Public Utility Commission Briefing, Honolulu, HI, December 2016.
4. A. Devie and M. Dubarry, EV cell degradation under electric utility grid operations: Impact of calendar aging & vehicle to grid strategies", Poster, EV Summit and Transportation Summit, Cocoa Beach, FL, USA, October 2016.
5. A. Devie and M. Dubarry, "Cycle and Calendar Aging Study of Lithium-Ion Batteries Under Various Vehicle-to-Grid Scenarios", 230th Meeting of the Electrochemical Society, Honolulu, HI, October 2016.
6. Sen, B., Ercan, T., and Tatari, O. (2017). "Does the electrification of U.S. heavy-duty trucks make a difference?" Transportation Research Board 97th Annual Meeting, 2017. Washington, DC.
7. Towfiq Rahman and Zhihua Qu, "The Role of Electric Vehicles for Frequency Regulation during Grid Restoration," 2017 IEEE PES General Meeting, 17PESGM2155, Chicago, IL, USA, July 16-20, 2017.
8. Farzad Aalipour, Azwirman Gusrialdi, and Zhihua Qu, "Distributed Optimal Output Feedback Control of Heterogeneous Multi-agent Systems under a Directed Graph," The 20th World Congress of the International Federation of Automatic Control, Toulouse, France, July 9-14, 2017
9. Towfiq Rahman, Roland Harvey, Zhihua Qu*, Marwan A. Simaan, "A Distributed Cooperative Load Control Approach for Ancillary Services in Smart Grid", the 2017 American Control Conference, Sheraton Seattle Hotel, May 24-26, Seattle, WA, USA.

10. Youngjun Joo and Zhihua Qu, "Cooperative Control of Heterogeneous Multi-agent Systems in Sampled-data Setting", the 55th IEEE Conference on Decision and Control, pp.2683-2688, ARIA Resort & Casino, Las Vegas, USA, December 2016.
11. K. Salimu**,** A. Kumar, and P. Sharma, "Use of Electrochemical Impedance Spectroscopy for Diagnostic of Lithium Ion Batteries", Tuskegee University, Alabama Academy of Science Annual Meeting held at University of South Alabama, February 23, 2017.
12. Kumasi Salimu, "EI Spectroscopy for Lithium Ion Batteries"**,** JARS Symposium (Joint Annual Research Symposium), Tuskegee University, March 17, 2017.

Publications:

1. M. Dubarry, A. Devie, and K. McKenzie, "Durability and Reliability of EV Batteries Under Electric Utility Grid Operations: Bidirectional Charging Impact Analysis," *Journal of Power Sources*, Submitted March 2017, *Project 9*
2. H. Valizadeh Haghi, S. Lotfifard, and Z. Qu, "Multivariate Predictive Analytics of Wind Power Data for Robust Control of Energy Storage," *IEEE Transactions on Industrial Informatics*, Vol.12, No. 4, pp. 1350-1360, 2016. *Project 13*
3. Y. Joo and Z. Qu, "Cooperative Control of Heterogeneous Multi-agent Systems in Sampled-data Setting," the *55th IEEE Conference on Decision and Control*, ARIA Resort & Casino, Las Vegas, USA, December 2016. *Project 13*
4. R. Harvey and Z., "Cooperative Control and Networked Operation of Passivity-Short Systems," in *Control of Complex Systems: Theory and Applications*, K. G. Vamvoudakis and S. Jagannathan (Eds.), pp. 499-518, Elsevier, Cambridge, MA, 2016. *Project 13*
5. Azwirman Gusrialdi and Zhihua Qu, "Distributed Scheduling and Cooperative Control for Charging of Electric Vehicles at Highway Service Stations," *IEEE Transactions on Intelligent Transportation Systems*, to appear. *Project 13*
6. Nan Qin, Gusrialdi, A. Brooker, P. T-Raissi, A. "Numerical Analysis of Electric Bus Fast Charging Strategies for Demand Reduction," Transportation Research Part A: Policy and Practice, DOI 10.1016/j.tra.2016.09.014. *Project 14*.
7. K. McKenzie, "EV Charging Stations," *Building Industry Hawaii*, and *Building Management Hawaii*, *(to press March 20, for publication April 2017). Project 17*
8. Onat, N., Noori, M., Kucukvar, M., Zhao, Y., Tatari, O., and Chester, M. (2017). "Exploring the Suitability of Electric Vehicles in the United States." Energy, Elsevier, 121(2017), 631-642, 2015 IF: 4.292. DOI: 10.1016/j.energy.2017.01.035, *Project 18.*
9. Zhao, Y., Noori, M., and Tatari, O. (2016). "Boosting the adoption and the reliability of renewable energy sources: Mitigating the large-scale wind power intermittency through vehicle to grid technology," Energy, Elsevier, 2015 IF: 4.292. DOI: 10.1016/j.energy.2016.11.112, *Project 18.*
10. M. Alirezaei, M. Noor and O. Tatari, "Getting to net zero energy building: Investigating the role of vehicle to home technology," Energy and Buildings, October 2016. *Project 18*
11. Coffman, M., Bernstein, P., *Wee, S. (2016). "Integrating Electric Vehicles and Residential Solar PV," *Transport Policy*, DOI 10.1016/j.tranpol.2016.08.008. *Project 19*.
12. Coffman, M., Bernstein, P., *Wee, S. (2016). "Electric Vehicles Revisited: A Review of Factors that Affect Adoption," *Transport Reviews*, DOI 10.1080/01441647.2016.1217282. *Project 19*.
13. Y. Liu, H. Xin, Z. Qu, and D. Gan, "An Attack-Resilient Cooperative Control Strategy of Multiple Distributed Generators in Distribution Networks," *IEEE Transactions on Smart Grid*, 2016. *Project 20*
14. Hamed Valizadeh Haghi and Zhihua Qu, "A Kernel-Based Predictive Model of EV Capacity for Distributed Voltage Control and Demand Response," IEEE Transactions on Smart Grid, to appear 2017. DOI: 10.1109/TSG.2016.2628367, *Project 20.*
15. Azwirman Gusrialdi, Zhihua Qu and Marwan A. Simaan, "Distributed Scheduling and Cooperative Control for Charging of Electric Vehicles at Highway Service Stations," IEEE Transactions on Intelligent Transportation Systems, to appear 2017. DOI: 10.1109/TITS.2017.2661958. *Project 20.*

16. M. Fripp, "Effect of Electric Vehicles on Design, Operation and Cost of a 100% Renewable Power System", White Paper No. 2017-03 *University of Hawaii Economic Research Organization (UHERO)*. March 29, 2017. *Project 21*.

Workshops/Conferences:

1. Sustainability Symposium 2017, January 9, 2017, Orlando, FL. Attended by Doug Kettles and Susan Schleith.
2. Go Solar Day, March 30, 2017, Plantation, FL. Doug Kettles and Jim Fenton attended and did presentations on electric transportation and solar PV to charge EVs.
3. 2016 Florida Automated Vehicles Summit, November 29, 2016, Tampa, FL. Attended by Doug Kettles.
4. Hosted EVTC's *EV Transportation & Technology Summit*, October 17-20, 2016. The four-day Summit attracted 90 attendees and had 14 sponsors for the event.
5. EV Symposium *"Achieving Zero-Emissions Mobility: The Role of Innovative Electric Vehicle Companies,"* hosted by UCConnect, University of California, Berkley. Attended by Doug Kettles, April 28, 2016, Berkley, California. (not previously reported)
6. *4th Annual Conference on Electric Roads & Vehicles (CERV),* hosted by SELECT at Utah State University. Attended by Doug Kettles and Richard Raustad (moderator), May 16-17, 2016, Logan Utah. (not previously reported)
7. *Conference on Use of Scenario Planning in Transportation Planning,* hosted by the Transportation Research Board (TRB). Attended by Doug Kettles, August 14-17, 2016, Portland Oregon. (not previously reported)

What do you plan to do during the next reporting period to accomplish the goals?

The R&D program and the research accomplishments for each of the 22 projects are presented in the Accomplishments section. For all active projects, future activities are presented as part of the accomplishments. As previously noted seven projects are considered completed and have the final reports posted. Final reports for the other 15 projects were being drafted and are in various stages of completion.

II. Products

List of products resulting from the program during the reporting period.

One EVTC Newsletter has been written and distributed by email during this reporting period. The section on "How have results been disseminated?" has presented the information on results dissemination which is also applicable to this section. Thus, reference is made to that section. The other major products are reports on the EVTC website and the TRB RiP and TRID databases. These websites and databases have been kept current with a web and data coordinator individual assigned to post all information. The EVTC web site includes a listing of the current research projects being conducted as well as educational information, technology transfer, news and events, publications, and resources applicable to the overall EVTC project.

III. Participants & Collaborating Organizations

What organizations have been involved as partners?

The three partner universities of the EVTC are the University of Central Florida's Florida Solar Energy Center and UCF's Civil, Environmental and Construction Engineering, Electrical Engineering and Computer Science departments, and the University of Hawai'i at Manoa and the Hawai'i Natural Energy Institute (HNEI) and Tuskegee University.

Organizations that have supplied direct funding to the EVTC are Nissan Motors and NovaCharge, who supplied equipment and funds for installation of a DC fast charging station at FSEC. General Electric

Corporation completed computer analysis of Hawaii electrical grid and Alabama Power has supported four Tuskegee University EVTC days. EV Summit sponsors included, Florida Power and Light, Orlando Utilities Commission, Tampa Electric Company, Gulf Power, Charged Electric Vehicles Magazine, Delaware North Corporation (NASA/KSC) and VIA Motors.

What organizations have been involved as collaborative partners?

External organization collaboration efforts have continued by all researchers. The collaborative partners are presented in the External Collaboration Accomplishments section.

IV. Changes/Impact

During the period, four projects (numbers 1, 6, 16 and 19) were completed and the final project reports forwarded to DOT and the required associated organizations. Three additional final reports (numbers 3, 7 and 10) are completed and posted on the EVTC web site, but not yet forwarded. Final reports for the other 15 projects were being drafted and are in various stages of completion. As of this time the project is nearly out of funding resources and it is only supporting two individuals at 50% each.

Significant events for this reporting period are EVTC researchers authored 7 project final reports, published 16 publications, made 12 presentations, attended 4 workshops and conferences, held or participated in 24 STEM events and have planned for 9 more STEM events. EVTC also held its 2nd EV Transportation & Technology Summit in October 2016 which had 90 attendees and 14 sponsors.

Administrative change during the period has been the adding of Richard Raustad as a project Co:PI.